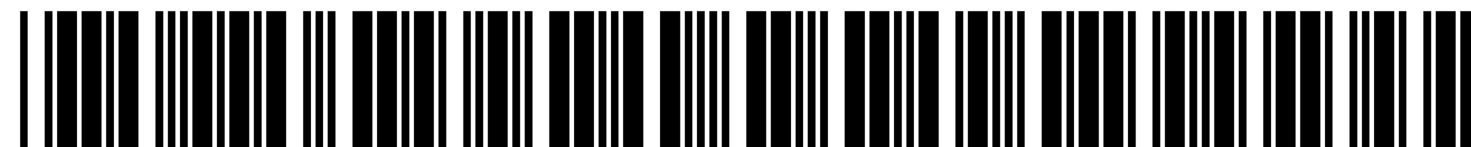

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Liu

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(54) **PACKAGE WITH THERMOELECTRIC POWER FEEDBACK LOOP**

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(51) **Int. Cl.**

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H01L 25/18	(2006.01)
H01L 23/367	(2006.01)
H01L 23/498	(2006.01)
H01L 35/00	(2006.01)
H01L 35/30	(2006.01)

(52) **U.S. Cl.**
CPC ***H01L 35/32*** (2013.01); ***H01L 23/3672*** (2013.01); ***H01L 23/49816*** (2013.01); ***H01L 25/18*** (2013.01); *H01L 35/00* (2013.01); *H01L 35/30* (2013.01)

(58) **Field of Classification Search**
CPC H01L 35/00; H01L 35/30; H01L 35/32; H01L 35/34; H01L 23/49816; H01L 23/3672; H01L 25/18
See application file for complete search history.

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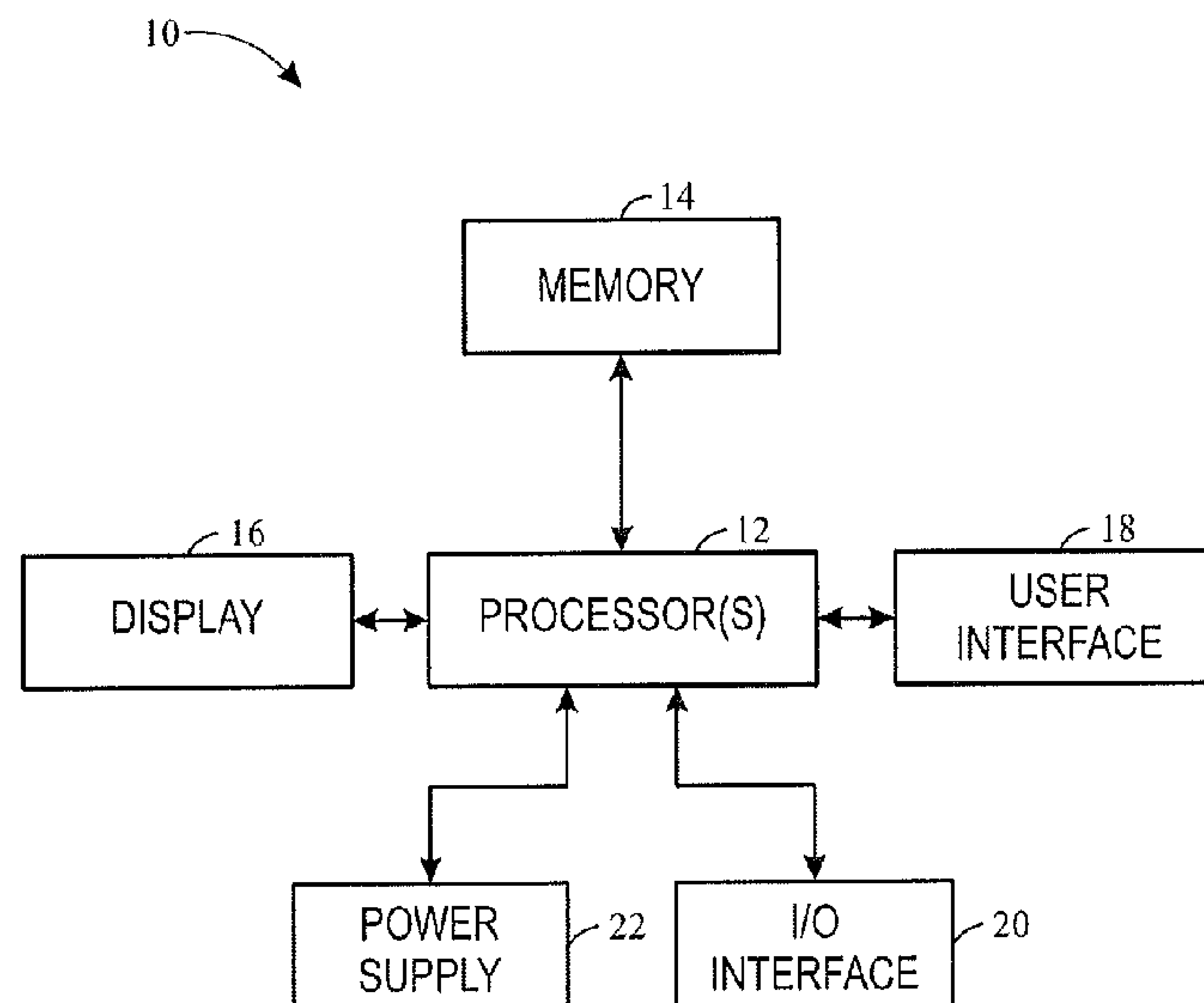
(57) **ABSTRACT**

A system includes an electronic device comprising one or more integrated circuit (IC) packages. The one or more IC packages include one or more IC chips and one or more thermoelectric power feedback systems. The one or more thermoelectric power feedback systems include one or more thermoelectric devices coupled to the one or more IC chips to generate power based on heat produced by the one or more IC chips. The one or more thermoelectric power feedback systems also include a power routing system that supplies the generated power to the one or more IC packages.

19 Claims, 3 Drawing Sheets



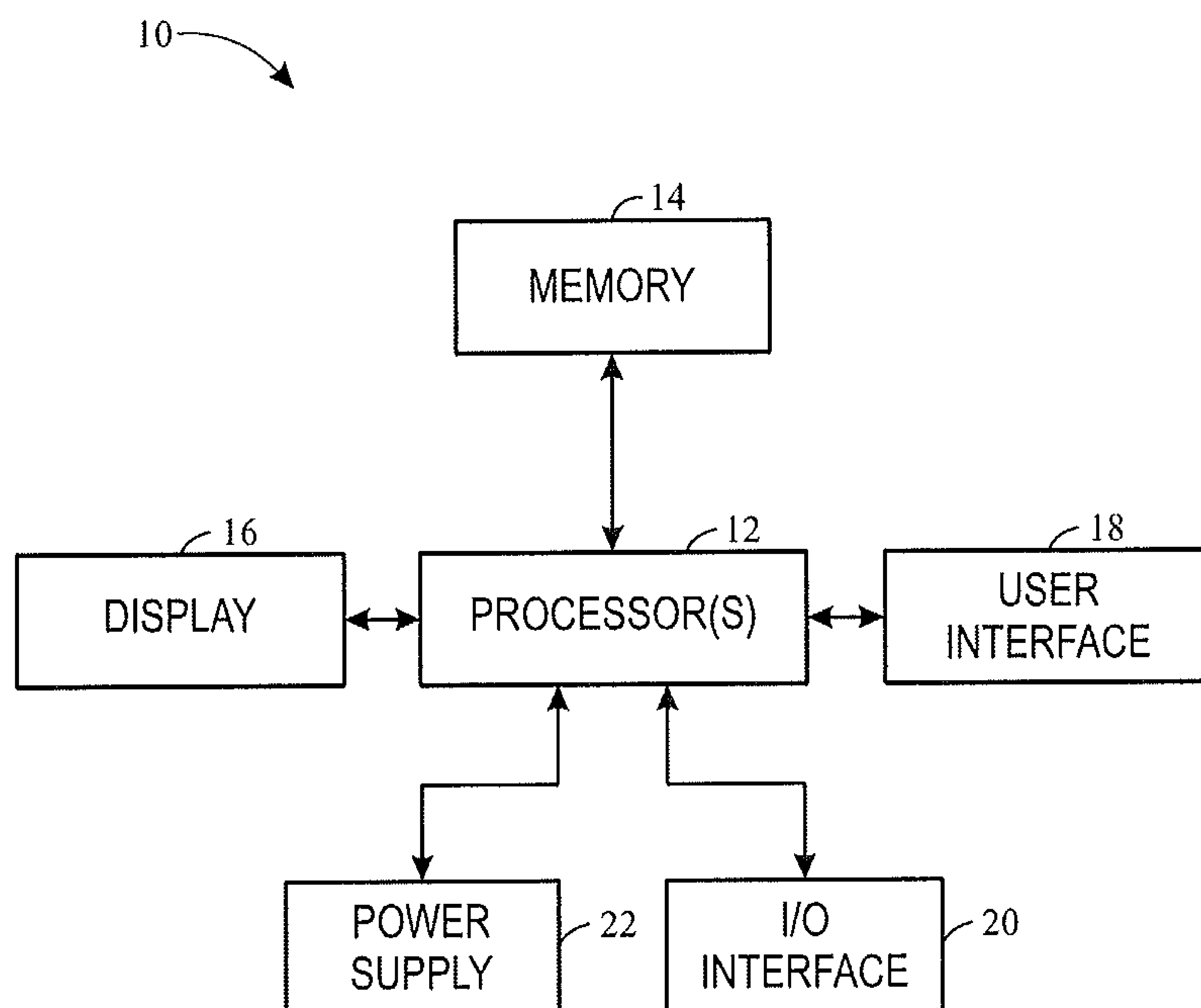


FIG. 1

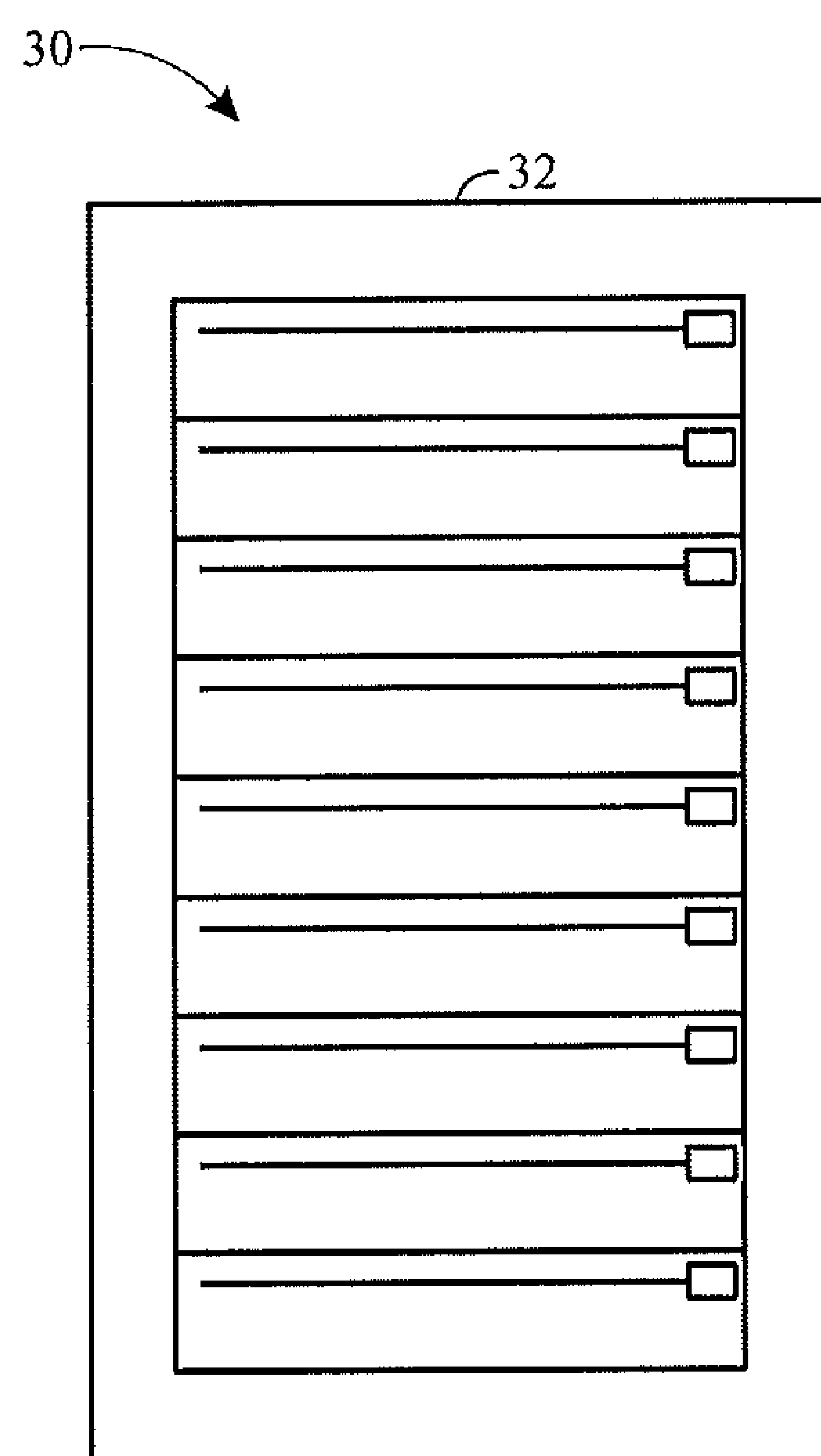


FIG. 2

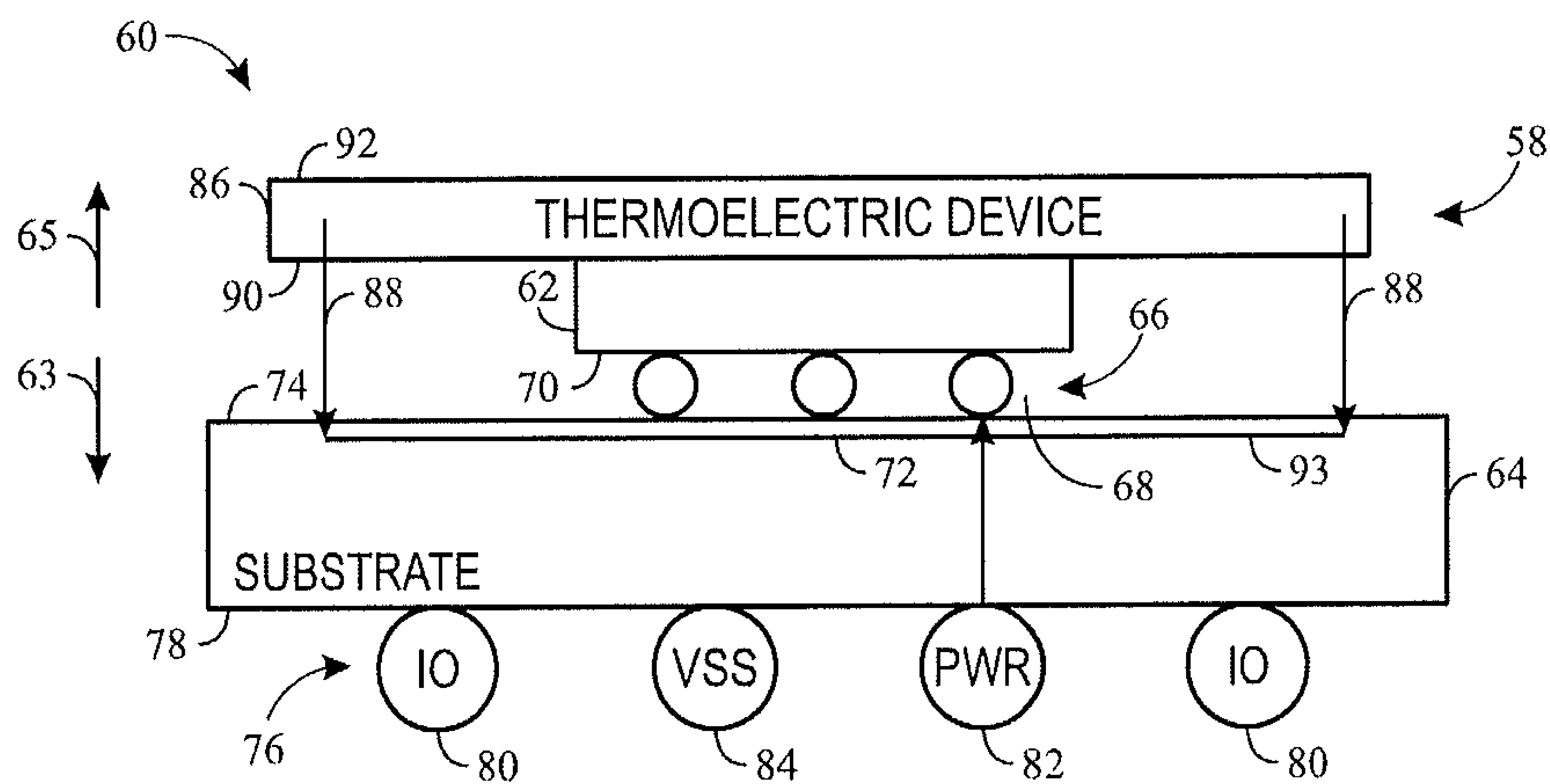


FIG. 3

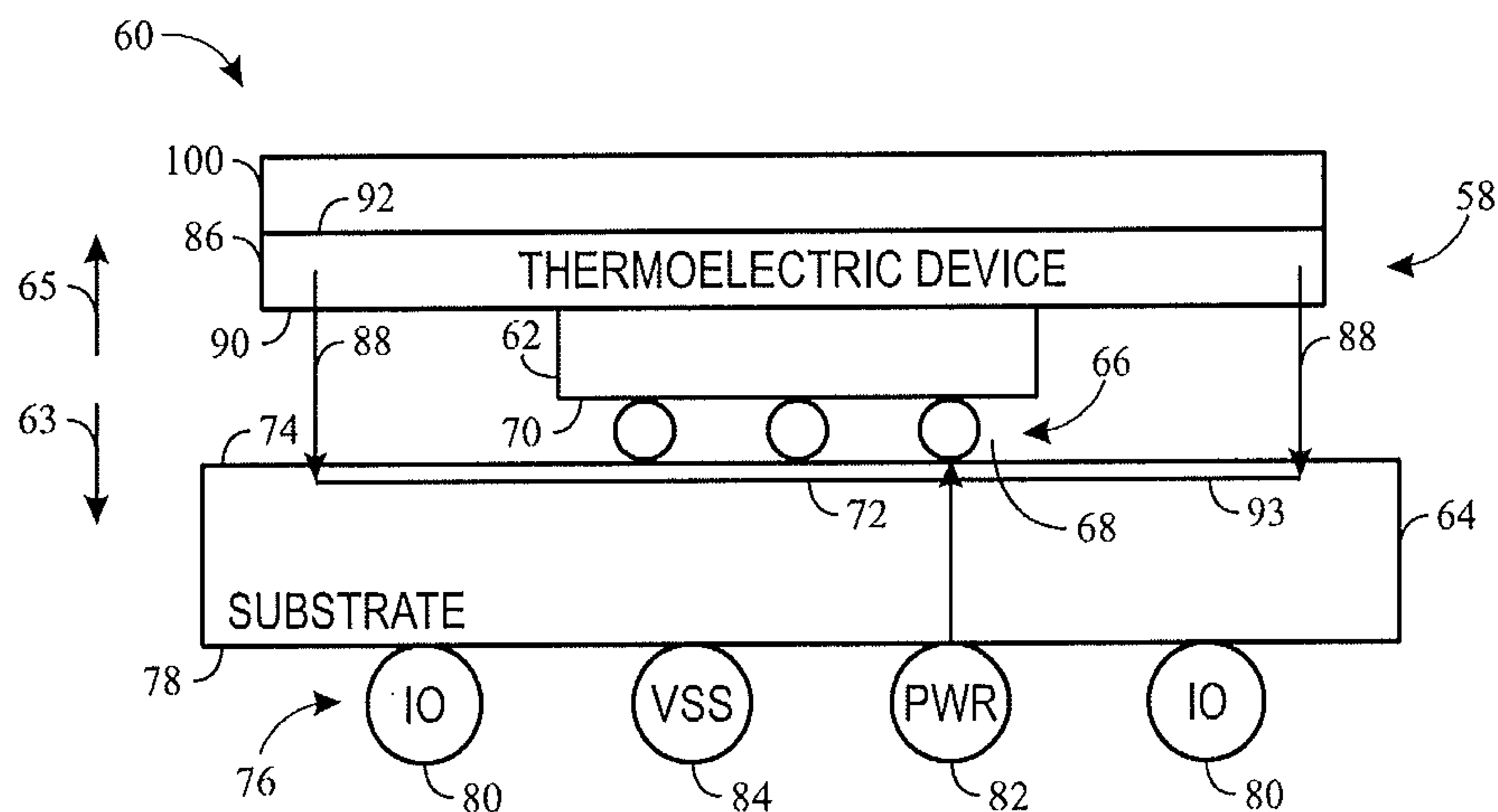


FIG. 4

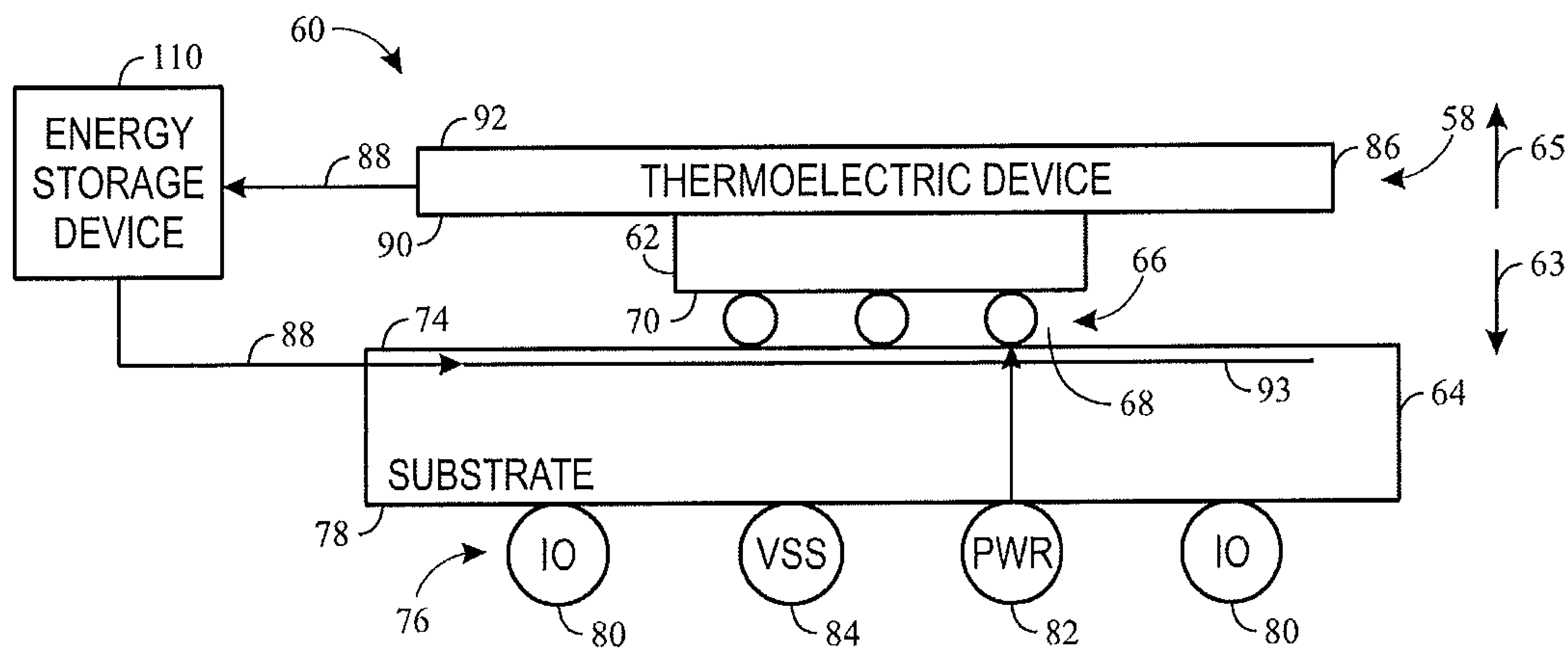


FIG. 5

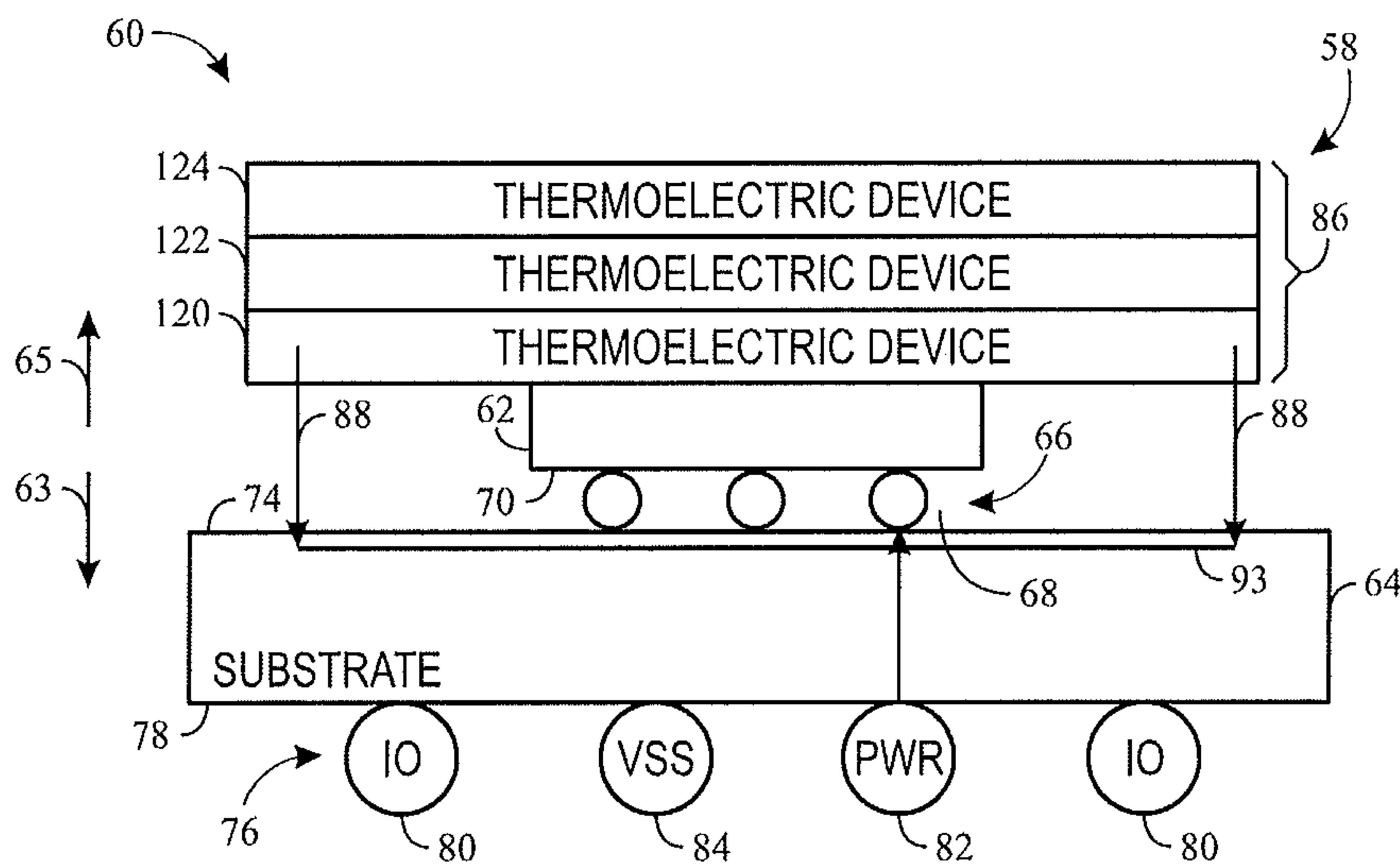


FIG. 6

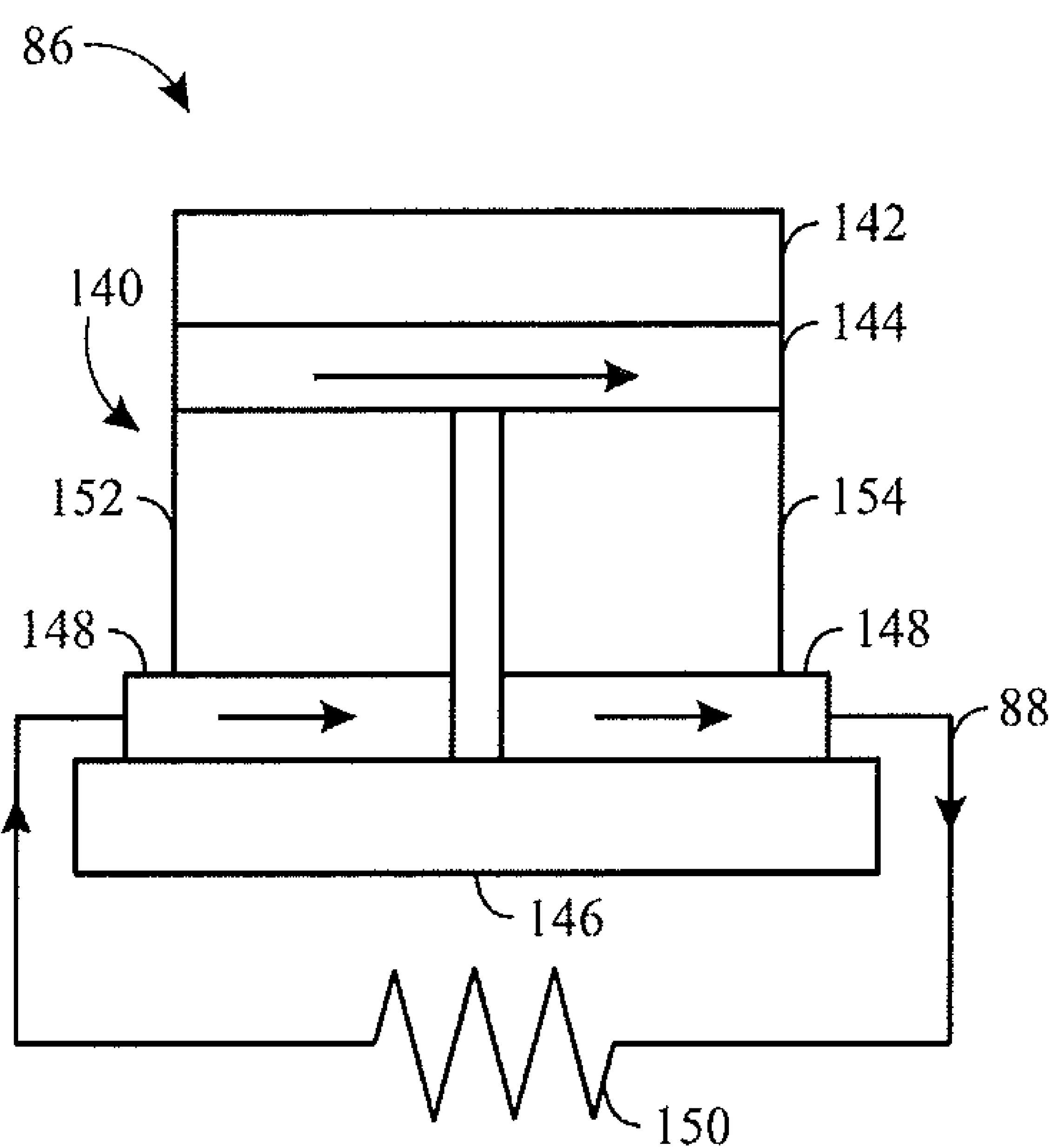


FIG. 7

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FPGA POWER	CONVERSION EFFICIENCY	RECYCLED POWER	CORE (LE) POWER	NEW CORE POWER	POWER BOOST	POWER BALL SAVING
200W	10%	20W	100W	120W	20%	~ 30

FIG. 8

PACKAGE WITH THERMOELECTRIC POWER FEEDBACK LOOP

BACKGROUND

The present disclosure relates generally to powering integrated circuits. More particularly, the present disclosure relates to a thermoelectric power feedback system implemented in packaging for integrated circuits.

This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

Integrated circuits (ICs) are a keystone of modern electronics. An integrated circuit (IC) package encapsulates IC chips or die and provides electrical connection from the IC chips to external electrical connections such as a printed circuit board (PCB). Electronic devices from small handheld devices to desktop systems to large servers may include one or more IC packages to perform a wide range of applications. An IC package may include power balls and ground balls for providing electrical paths and grounds to supply power from the PCB to the IC chips, and it may include input/output (I/O) balls for routing I/O signals. To provide higher computing capability and feature utilization, both power supply to the IC chip and I/O routing need to be enhanced. One possible approach to achieve such goal is by increasing the size of the IC package as to add a greater number of power, ground, and I/O balls to enhance power supply and I/O routing. However, increasing the IC package size may add cost to IC package fabrication and at times may not be an option in space-constrained applications. Alternatively, if the IC package size remains unchanged, adding a greater number of power and ground balls needs to be compensated by reducing the number of I/O balls. However, a reduction in the number of I/O balls may adversely impact computing capability and feature utilization of the electronic devices.

SUMMARY

A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

Present embodiments relate to a thermoelectric power feedback system implemented in IC package(s) in an electronic device. The thermoelectric power feedback system may generate additional electrical power by converting heat generated by an IC chip to power that may be fed back to the chip. As such, the thermoelectric power feedback system may enhance power support and feature utilization of the electronic device without increasing the size of IC package (s). In addition, the thermoelectric power feedback system may aid in thermal management of the electronic device as it recycles waste heat from the IC chips.

In one embodiment, a system includes an electronic device comprising one or more integrated circuit (IC) packages. The one or more IC packages include one or more IC chips and one or more thermoelectric power feedback systems. The one or more thermoelectric power feedback systems include one or more thermoelectric devices coupled to the one or more IC chips to generate power based on heat produced by the one or more IC chips. The one or more thermoelectric power feedback systems also include a power routing system that supplies the generated power to the one or more IC packages.

In another embodiment, an integrated circuit (IC) package includes one or more IC chips and one or more thermoelectric power feedback systems. The one or more thermoelectric power feedback systems include one or more thermoelectric devices coupled to the one or more IC chips to generate power based on heat generated by the one or more IC chips. The one or more thermoelectric power feedback systems also include a power routing system that supplies the generated power to the one or more IC packages.

In another embodiment, an integrated circuit (IC) package includes one or more IC chips. The IC package includes a first number of power balls, a second number of ground balls, and a third number of input/output (I/O) balls that provide electrical connection between the one or more IC chips and a printed circuit board of an electronic device. The IC package also includes one or more a thermoelectric power feedback systems that generate and supply additional energy to the IC package. The one or more thermoelectric power feedback systems include one or more thermoelectric devices coupled to the one or more IC chips to generate electrical power based on heat produced by the one or more IC chips. The one or more thermoelectric power feedback systems also include a power routing system that couples the one or more thermoelectric devices to a power grid of the IC package.

Various refinements of the features noted above may be employed in relation to various aspects of the present disclosure. Further features may also be incorporated in these various aspects as well. These refinements and additional features may be employed individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present invention alone or in any combination. The brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of embodiments of the present disclosure without limitation to the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

Advantages of the present disclosure may become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. **1** is a block diagram of an electronic device in which one or more thermoelectric power feedback systems may be used to aid power supply, in accordance with an embodiment;

FIG. **2** is a perspective view of a server representing an embodiment of the electronic device of FIG. **1**, in accordance with an embodiment;

FIG. **3** is a schematic diagram of an IC package of the electronic device of FIG. **1** illustrating the thermoelectric power feedback system implemented in the IC package, wherein power is generated via a thermoelectric device, in accordance with an embodiment;

FIG. **4** is a schematic diagram of an integrated circuit (IC) package of the electronic device of FIG. **1** illustrating the

thermoelectric power feedback system implemented in conjunction with a heat sink in the IC package, in accordance with an embodiment;

FIG. **5** is a schematic diagram of an integrated circuit (IC) package of the electronic device of FIG. **1** illustrating the thermoelectric power feedback system coupled to an energy storage device to store generated power, in accordance with an embodiment;

FIG. **6** is a schematic diagram of an integrated circuit (IC) package of the electronic device of FIG. **1** illustrating the thermoelectric power feedback system implemented in the IC package, wherein a plurality of thermoelectric devices are used to enhance power generation, in accordance with an embodiment;

FIG. **7** is a schematic diagram of an thermoelectric device of the thermoelectric power feedback system illustrating a power generation mechanism, in accordance with an embodiment; and

FIG. **8** is a table illustrating enhanced power support in relation to device feature utilization.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

One or more specific embodiments of the present disclosure will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure. The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical.

As mentioned above, if the size of an IC package remains unchanged, adding a greater number of power and ground balls to enhance power supply needs to be compensated by reducing the number of I/O balls. However, a reduction in the number of I/O balls may mean a trade-off in computing capability and feature utilization of an electronic device. In addition, heat developed during the operation of ICs needs to be dissipated as to maintain the performance of the electronic device. Embodiments of the present disclosure relate to providing a thermoelectric power feedback system that recycles heat (e.g., waste heat) dissipated from ICs to generate additional electricity to power the ICs and/or any other power-hungry components in an IC package. As such, the thermoelectric power feedback system not only helps remove heat from the IC package, but also generates additional power to aid power supply to the IC package. With the additional power generated from waste heat, the IC package may include a fewer number of power and ground balls, and the space (e.g., chip real estate) saved from the reduction in the number of power and ground balls may be used to add more I/O balls such that the power support and feature utilization of the electronic device may be enhanced without increasing the size of the IC package.

With the foregoing in mind, FIG. **1** shows a block diagram of an electronic device **10** that may integrate one or more thermoelectric power feedback systems as to aid power supply. The electronic device **10** according to an embodiment of the present disclosure may include, among other things, one or more processor(s) **12**, a memory **14**, a display **16**, a user interface (UI) **18**, an input/output (I/O) interface **20**, and a power supply **22**. The various functional blocks shown in FIG. **1** may include hardware elements (including circuitry), software elements (including computer code stored on a computer-readable medium) or a combination of both hardware and software elements.

The processor(s) **12** may include one or more application specific integrated circuits (ASICs), one or more field programmable gate arrays (FPGAs), one or more programmable circuits, one or more system-on-chip (SoC) circuits, one or more system-on-package (SoP) circuits, one or more system-in-chip (SiP) circuits, one or more general purpose processors, or any combination thereof. The memory **14** may include volatile memory, such as random access memory (RAM), and/or non-volatile memory, such as read-only memory (ROM), optical drives, hard disc drives, or solid-state drives. The memory **14** may store data or information and one or more sets of instructions (e.g., processor-executable instructions) implemented to enable operation of the electronic device **10**. The display **16** may include one or more organic light emitting diode (OLED) displays, one or more liquid crystal display (LCD) panels, one or more active-matrix organic light emitting diode (AMOLED) displays, or any other one or more output devices to present information in visual form to users. The user interface (UI) **18** may include one or more graphical user interfaces, one or more touch screens, one or more command line interfaces, or any other types of interfaces to allow users to interact with the electronic device **10**. The I/O interface **20** may enable the electronic device **10** to interface with various other electronic devices. The power supply **22** may be one or more batteries (e.g., rechargeable batteries) or a power supply unit (PSUs) that converts a general-purpose alternating current (AC) electric power supply to low-voltage regulated direct-current (DC) power for various elements of the electronic devices **10**. It should be noted that the various elements (e.g., hardware and/or software elements) shown in FIG. **1** may include ICs (e.g., one or more IC chips, one or more IC packages) to enable the various elements to perform their functions. Within the one or more IC packages, one or more thermoelectric power feedback systems may be implemented to enhance power and feature utilization of the electronic device **10**.

It should also be noted that FIG. **1** is merely one example of a particular implementation and is intended to illustrate the types of components that may be present in the electronic device **10**. Further, the electronic device **10** may represent a server **30** depicted in FIG. **2** or any other type of electronic device that might benefit from the present technique, such as a handheld electronic device, a wearable electronic device, or similar devices. The depicted server **30** may include a housing or enclosure **32**, as well as one or more of the elements described in FIG. **1**. The server **30** may be an application server, a catalog server, a communications server, a computing server, a database server, a game server, a media server, a web server, and any other type of server. The server **30** may rely on one or more IC packages to enable various applications and features. Within the one or more IC packages, one or more thermoelectric power feedback systems may be implemented as to enhance power supply and feature utilization of the server **30**.

A thermoelectric power feedback system **58** may be implemented in one or more IC packages **60** used in the electronic device **10** shown in FIG. **1**. The one or more IC packages **60** may be system-on-chip (SoC), system-on-package (SoP), system-in-package (SiP), power ICs, etc. FIGS. **3-6** each shows a schematic diagram of a thermoelectric power feedback system **58** implemented in an IC package **60** in accordance with an embodiment. In the illustrated embodiments, the IC package **60** includes one or more IC chips **62** and a substrate **64**. In the following descriptions, a direction **63** pointing away from the chip **62** and toward the substrate **64** is referred to as the "bottom," whereas a direction **65** pointing away from the substrate **64** and toward the chip **62** is referred to as the "top." The IC chip **62** is coupled and electrically connected to the substrate **64** through a plurality of conductive contacts **66** within a bonding area **68**. For example, the plurality of contacts **66** may be solder spheres, coupled to contact pads (not shown) on the IC chip **62**, to facilitate electrical connections between a bottom surface **70** of the IC chip **62** and the corresponding contact pads (not shown) disposed at a top surface **74** of the substrate **64**.

It may be appreciated that since the plurality of contacts **66** may be be densely distributed on the bottom surface **70** of the IC chip **62**, it may not be convenient to bond such contacts **66** to a PCB or motherboard, hence, the substrate **64** may spread out the densely packed contacts **66** to a less dense spacing such that the I/O signals and power and ground contacts may be connected to the PCB. For example, the IC package **60** may include a plurality of conductive contacts such as balls (e.g., solder balls) **76** to couple and electrically connect a bottom surface **78** of the substrate **64** to the PCB. The plurality of balls **76** includes a plurality of I/O balls **80** for signal input/output and a plurality of power balls **82** and ground balls **84** for supplying power to the IC chip **62**. Each of the plurality of contacts **66** is electrically connected to a corresponding one of the plurality of balls **76** (e.g., through the contact pads and through one or more electrical vias through the substrate **64**). While the ratio of the I/O balls **80** to power balls **82** to ground balls **84** may change to meet certain design requirements of the IC package **60** (e.g., to reduce the package production cost, improve device performance, and reduce signal noise, etc.), the total number of the plurality of balls **76** may not be changed due to area constraint of the IC package **60** (e.g., limited chip real estate). For example, if the IC package size remains unchanged, adding a greater number of power and/or ground balls needs to be compensated by reducing the number of I/O balls, and vice versa.

In the illustrated embodiments in FIGS. **3-6**, the IC package **60** also includes the thermoelectric power feedback system **58** to enhance power supply by generating additional power based on heat generated by the IC chip **62** (e.g., recycling waste heat). In particular, the thermoelectric feedback system **58** includes one or more thermoelectric devices **86** coupled to the IC chip **62** and a power routing system **88** (e.g., bonding wires made of electrical conductive metal and/or metal alloys) to supply generated additional power to the IC chip **62** and/or other power demanding components, among other things, in the IC package **60**. The thermoelectric device **86** includes a bottom side **90** and a top side **92**, opposite to the bottom side **90** (e.g., in the direction **65**), wherein the bottom side **90** directly contacts the IC chip **62**, and the temperature at the bottom side **90** is higher than the temperature at the top side **92**. Based on such temperature difference between the bottom side **90** and the top sides **92**, the thermoelectric device **86** may generate electricity and at the same time remove at least a portion of the heat generated by the IC chip **62**, as will be discussed in detail in FIG. **7**. As such, additional power may be generated by the thermoelectric power feedback system **58** to aid power supply to the IC package **60**. It may also be appreciated that implementation of the thermoelectric power feedback system **58** may also enhance thermal management of the IC package (e.g., removing heat form the IC chip **62**) as to main the functionality of the electronic device **10**. In one embodiment, as shown in FIG. **3**, the power routing system **88** (e.g., bonding wires made of electrical conductive metal and/or metal alloys) of the thermoelectric power feedback system **58** may couple to a power grid **93** of the IC package **60** such that the generated additional power may be directly fed to power the IC package **60** including the IC chip **62**.

In one embodiment, as shown in FIG. **4**, the thermoelectric device **86** of the thermoelectric power feedback system **58** is used in conjunction with one or more heat removing components such as a heat sink **100** to dissipate heat generated by the IC chip **62**. The thermoelectric device **86** is coupled to both the IC chip **62** and the heat sink **100** such that the bottom side **90** directly contacts the chip **62** and the top side **92** directly contacts the heat sink **100**. As such, residual heat or heat that is not recycled or utilized by the thermoelectric device **86** may be dissipated by the heat sink **100**. It may be appreciated that the one or more heat removing component may not be limited to a passive cooling component such as the heat sink **100**, and may include any other passive or active cooling devices such as closed-loop microfluidic cooling devices, cooing fins, cooling cavities, cold plates, air cooling devices, etc.

In one embodiment, as shown in FIG. **5**, the power routing system **88** (e.g., bonding wires made of electrical conductive metal and/or metal alloys) may include an energy storage device **110** such as a battery, a capacitor, or a combination thereof, and the energy storage device **110** is coupled to both the thermoelectric device **86** and the power grid **93**. As such, the generated power by the thermoelectric device **86** may be stored in the energy storage device **110** and upon a demand fed to the IC chip **62** and/or other power demanding components, among other things, of the IC package **60**.

In one embodiment, as shown in FIG. **6**, the thermoelectric power feedback system **58** includes a plurality of thermoelectric devices **86** adjacent to one another to enhance the power generating efficiency. The plurality of thermoelectric devices **86** includes a first thermoelectric device **120**, a second thermoelectric device **122**, and a third thermoelectric device **124** stacked on top of the IC chip **62** in the direction **65**. The first thermoelectric device **120** contacts the IC chip **62**, the second thermoelectric device **122** contacts the first and the third thermoelectric devices **120** and **124**, and the third thermoelectric device **124** contacts the second thermoelectric device **122**. The first thermoelectric device **120** may recycle heat generated by the IC chip **62** to generate power, the second thermoelectric device **122** may recycle residual heat (e.g., heat that is not recycled by the first thermoelectric device **120**) to generate power, and the third thermoelectric device **124** may still recycle residual heat (e.g., heat that is not recycled by the first and second thermoelectric devices **120** and **122**) to generate power.

As such, in cases that a single thermoelectric device (e.g., the first thermoelectric device **120**) is not able to recycle all of the heat generated by the IC chip **62**, the residual heat may be recycled by additional thermoelectric devices (e.g., the second thermoelectric device **122**, the third thermoelectric device **124**, and so on) as to enhance efficiency or power generating efficiency of the thermoelectric power feedback

system **58**. Herein the efficiency of the thermoelectric power feedback system **58** is defined as electrical energy generated or power generated for one hour divided by heat energy absorbed at the thermoelectric device(s) **86**. For example, if the plurality of thermoelectric devices **86** each has an efficiency of approximately 10% (e.g., approximately 10% of heat energy absorbed at the thermoelectric device **86** is converged to electrical energy), having the first, second, and third thermoelectric devices **120**, **122**, and **124** stacked together may achieve approximately 27.1% efficiency (e.g., 100%−(100%−10%)×(100%−10%)×(100%−10%)=27.1%) as compared to an approximately 10% efficiency if only one thermoelectric device is used.

Although in the illustrated embodiment the plurality of thermoelectric devices **86** includes only three thermoelectric devices, any number of thermoelectric devices **86** may be incorporated and arranged in any configurations suitable to recycle heat generated by the IC chip **62** and to generate power. Further, it may be appreciated that the efficiency of the thermoelectric power feedback system **58** may generally increase with the number of thermoelectric devices **86**. The generated power may be fed back to power the chip **62** and/or other power demanding components, among other things, through the power routing system **88** (e.g., bonding wires made of electrical conductive metal and/or metal alloys) connected to the power grid **93** of the IC package **60**. In addition, thermoelectric device(s) **86** and the power routing system **88** may be arranged in any combination set forth above in FIGS. **3**-**6**.

FIG. **7** shows a schematic diagram of the thermoelectric device **86** of the thermoelectric power feedback system **58** illustrating a power generation mechanism. It should be noted that the thermoelectric device **86** may be any suitable thermoelectric generator that coverts thermal energy into electrical energy based on the thermoelectric effect. In particular, a difference in temperature is used to create an electric potential based on Seebeck effect (e.g., converting temperature difference to electrical current).

In the illustrated embodiment, the thermoelectric device **86** includes a thermoelement junction **140** coupled to a hot element or heat source **142** (e.g., element of higher temperature) at a first interface **144** and coupled to a cold element **146** (e.g., element of lower temperature) at a second interface **148**. The hot element **142** discussed herein may refer to the IC chip **62**, and the cold element **146** may refer to any components having a lower temperature than the IC chip **62**, including the one or more heat removing components such as the heat sink **100**. One or both of the first interface **144** and the second interface **148** may be electrically coupled (e.g., via wires made of electrical conductive metal and/or metal alloys) to the power routing system **88** of the thermoelectric power feedback system **58** such that electrical current generated by the thermoelectric device **86** may be flown to a load **150**. The load **150** discussed herein may refer to any power demanding components in the IC package **60** as set forth above.

The thermoelement junction **140** may generate electrical energy based on a temperature difference between the hot element **142** and the cold element **146**. In particular, the thermoelement junction **140** may include any suitable thermoelectric materials showing prominent Seebeck effect, such as bismuth telluride, lead telluride, silicon germanium, any other suitable semiconductors, or a combination thereof. Further, the thermoelectric materials may also be in any suitable forms, including alloys, complex crystals, and multiphase nanocomposites. In the illustrated embodiment, the thermoelement junction **140** includes an n-type semiconductor **152** coupled to a p-type semiconductor **154**. In operation, providing a temperature difference across the thermoelement junction **140**, the hot element **142** drives electrons in the n-type semiconductor **152** toward the cold element **146**, creating a current. Correspondingly, holes in the positive element **154** flows in the direction of the electrical current, resulting in the current flow (e.g., as indicated by the arrows) in a closed circuit of the thermoelement junction **140**. It may be appreciated that as long as a temperature difference is present, an electrical current can be generated within the thermoelement junction **140** flown to the power routing system **88** of the thermoelectric power feedback system **58**.

FIG. **8** is a table **170** illustrating an enhanced power support based on implementation of the thermoelectric power feedback system **58** in the IC package **60**. In the illustrated embodiment, the IC package **60** includes the thermoelectric power feedback system **58** to help aid power supply to the IC chip **62** for field-programmable gate arrays (FPGAs). In this example, the FPGAs may consume approximately 200 watts (W) of power, among which approximately 100 W is the core power consumed by logic elements (LE). The thermoelectric power feedback system **58** may include a thermoelectric device **86** having approximately 10% efficiency (e.g., approximately 10% of heat energy absorbed at the thermoelectric device **86** is converged to electrical energy). Accordingly, the thermoelectric device **86** may generate approximately 10% of the 200 W (e.g., 20 W) by recycling heat generated by the FPGA, and the generated power (e.g., 20 W) may be supplied to help powering the LE of the FPGA. In particular, the generated 20 W may be fed to the LE such that the new core power is allocated to approximately 120 W. In other words, the FPGA receives an approximately 20% power boost in the LE (e.g., increased from 100 W to 120 W).

In this example, it is also estimated that the FPGA may require approximately 30 power balls **82** to supply approximately 20 W of power to the chip **62**. As such, with 20 W of additional power generated by the thermoelectric power feedback system **58**, the IC package **60** may save or replace approximately 30 power balls **82** (along with approximately 30 corresponding ground balls **84**) for other utilization. For example, the power and ground balls **80** and **82** may be replaced by I/O balls **80** to enhance signal input/output. As such, the power supply and feature utilization of the FPGA may be enhanced without increasing the size of the FPGA and without adding more power and ground balls **80** and **82**. It should be noted that thermoelectric power feedback system **58** may include more than one thermoelectric devices **86** such that the power generating efficiency may increase and result in greater saving in the number of power balls **82** (and correspondingly ground balls **84**). Such reduction in package power ball requirement may reduce the device manufacturing cost and enhance power support for higher feature utilization and power efficient applications.

While the embodiments set forth in the present disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the disclosure is not intended to be limited to the particular forms disclosed. The disclosure is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the following appended claims.

What is claimed is:

1. A system comprising:

an electronic device comprising one or more integrated circuit (IC) packages, comprising:

one or more IC chips disposed on a substrate;
one or more thermoelectric power feedback systems, comprising:
one or more thermoelectric devices coupled to the one or more IC chips to generate power based on heat produced by the one or more IC chips; and
a power routing system configured to directly, electrically couple the one or more thermoelectric devices to a power grid disposed on the substrate such that the generated power is directly fed to the one or more IC chips; and
a plurality of conductive contacts configured to couple the one or more IC chips to a printed circuit board of the electronic device, wherein the plurality of conductive contacts comprises a plurality of power balls and a plurality of input/output (I/O) balls, wherein the power routing system is configured to supply the generated power to the one or more IC chips such that one or more of the plurality of conductive contacts that would otherwise be implemented as one or more power balls to supply a supply power equivalent to the generated power, are implemented as one or more I/O balls.

2. The system of claim **1**, wherein the one or more IC packages comprise a plurality of ground balls that couple the one or more IC chips to the printed circuit board of the electronic device.

3. The system of claim **1**, wherein the one or more thermoelectric power feedback systems each has a power generating efficiency of at least approximately 10%.

4. The system of claim **1** comprises a heat sink coupled to the one or more thermoelectric devices.

5. The system of claim **4**, wherein the one or more thermoelectric devices are disposed between the heat sink and the one or more IC chips.

6. The system of claim **1**, wherein the one or more thermoelectric devices comprise a plurality of thermoelectric devices stacked on one another.

7. The system of claim **6**, wherein the one or more thermoelectric devices are stacked on one another in a direction away from the one or more IC chips.

8. The system of claim **1**, wherein the power routing system comprises an energy storage device.

9. An integrated circuit (IC) package comprising:
a substrate;
one or more IC chips disposed on the substrate;
one or more thermoelectric power feedback systems, comprising:
one or more thermoelectric devices coupled to the one or more IC chips to generate power based on heat generated by the one or more IC chips, wherein the one or more thermoelectric devices comprises a plurality of thermoelectric devices vertically stacked on one another; and
a power routing system disposed on the substrate and configured to supply the generated power from the one or more thermoelectric devices directly to the IC package; and
a plurality of conductive contacts configured to couple the one or more IC chips to a printed circuit board of an electronic device, wherein the plurality of conductive contacts comprises a plurality of power balls and a plurality of input/output (I/O) balls, wherein the power routing system is configured to supply the generated power to the one or more IC chips such that one or more of the plurality of conductive contacts that would otherwise be implemented as one or more power balls to supply a supply power equivalent to the generated power, are implemented as one or more I/O balls.

10. The IC package of claim **9**, wherein the one or more IC packages comprise a plurality of ground balls that provide electrical connection between the one or more IC chips and the electronic device.

11. The IC package of claim **9**, wherein the one or more thermoelectric power feedback systems each has a power generating efficiency of at least approximately 10%.

12. The IC package of claim **9** comprises a heat sink coupled to the one or more thermoelectric devices.

13. The IC package of claim **12**, wherein the one or more thermoelectric devices are disposed between the heat sink and the one or more IC chips.

14. The IC package of claim **9**, wherein the power routing system comprises an energy storage device.

15. An integrated circuit (IC) package comprising:
one or more IC chips;
a plurality of conductive contacts comprising a first number of power balls, a second number of ground balls, and a third number of input/output (I/O) balls that provide electrical connection between the one or more IC chips and a printed circuit board of an electronic device; and
one or more thermoelectric power feedback systems that generate and supply electrical power to the IC package comprising:
one or more thermoelectric devices coupled to the one or more IC chips to generate the electrical power based on heat produced by the one or more IC chips; and
a power routing system that couples the one or more thermoelectric devices to a power grid of the IC package, wherein the power routing system supplies the generated electrical power to the power grid and to the one or more IC chips without routing the generated electrical power through a power ball of the first number of power balls, and wherein the power routing system is configured to supply the generated electrical power to the one or more IC chips such that one or more of the plurality of conductive contacts that would otherwise be implemented as one or more power balls to supply a supply power equivalent to the generated electrical power, are implemented as one or more I/O balls.

16. The IC package of claim **15**, wherein the one or more thermoelectric power feedback systems each has a power generating efficiency of at least approximately 10%.

17. The IC package of claim **15**, wherein the one or more thermoelectric devices comprise a number of thermoelectric devices stacked on one another as to increase a power generating efficiency of the one or more thermoelectric power feedback systems.

18. The IC package of claim **15** comprises a heat sink coupled to the one or more thermoelectric devices.

19. The IC package of claim **15** comprises an energy storage device.

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